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Case Series

Mobility Training for Patients Recovering from Neurological Injuries with Kickstart®: A Case Series

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Abstract

Despite numerous advances in rehabilitation techniques for people recovering from neurological injuries, many patients reach plateaus in their walking recovery and are unable to fully regain their independence. Technologies such as robotic exoskeletons seek to improve walking ability for neurological patients, but their cost severely limits widespread adoption. New affordable technologies that can accelerate neurological rehabilitation are needed. In this case series, we investigate a bio-inspired device called Kickstart with two chronic stroke survivors and one participant with a chronic incomplete spinal cord injury. Participants were assessed in terms of walking speed and walking endurance. All three participants demonstrated improved walking speed to reach elevated levels of community ambulation, and all three participants exhibited functional return in the form of less reliance on Kickstart. The results of this study suggest that Kickstart can be an effective tool in accelerating walking recovery for patients with chronic neurological injuries.

Keywords: Stroke; Spinal cord injury; Rehabilitation; Physical therapy; Neurorehabilitation; Exotendon

Abbreviations

T-10: Tenth Thoracic Vertebrae; m: Meter; m/s: Meters per Second

Background and Purpose

To actively assist ambulation for persons with injuries and disabilities, much work has been done in the area of powered exoskeletons [1-4]. These devices consist of an external support structure with powered, articulated joints and are touted to provide unbridled potential as assistive devices for the mobility-impaired. However, the motors and control circuitry required to operate powered exoskeletons result in immense financial costs for the systems that limit their clinical adoption. New technologies that are affordable for widespread use are needed to accelerate walking recovery for patients with neurological injuries. For this case series, we investigated the use of Kickstart, a bio-inspired neurorehabilitation device, with three patients with chronic neurological injuries. Instead of electronics or stimulation, Kickstart utilizes an elastic based Exotendon™ technology inspired by the anatomy of horses. In the hind limbs of a horse, long tendons span multiple joints. During the stance phase of gait, the tendons stretch and store energy which is later returned to initiate swing phase with less work required from the muscles [5-13]. Kickstart's Exotendon functions similarly by storing energy during the stance phase and slowing the progression of the tibia relative to the foot to provide a greater sense of stability and to promote a longer contra lateral step. Then, when the user shifts his/her weight to the contra lateral limb, the Exotendon returns energy to initiate the swing phase of gait (Figure 1). This is intended to enable users to perform the proper walking motions with better endurance which has been documented as key factors in bringing about therapeutic carryover following neurological injury [14]. We now present three clinical cases of patients with chronic neurological injuries using Kickstart.

Case 1: Incomplete Spinal Cord Injury

Participant 1 was a male with an incomplete T-10 spinal cord injury secondary to spinal fusion surgery seven years prior to the study. He lived at home and was independent in self care. He stood in a stander daily, transferred independently, and could walk very short distances with a walker with close guarding.

He was able to walk independently in a pool with flotation devices. Participant 1 presented with weakness in both lower extremities impacting all muscle groups. The patient had 2-/5 strength on the left and 3/5 strength on the right for hip flexors, knee extensors, ankle

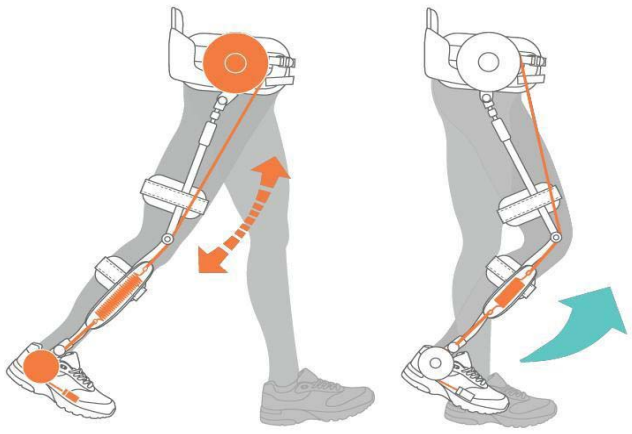

Figure 1: The Kickstart consists of a belt, external support structure, and an Exotendon which acts like an artificial tendon to store and release energy throughout the gait cycle. Using the Exotendon, Kickstart provides users with swing assistance, added stability and feedback for proper gait mechanics.

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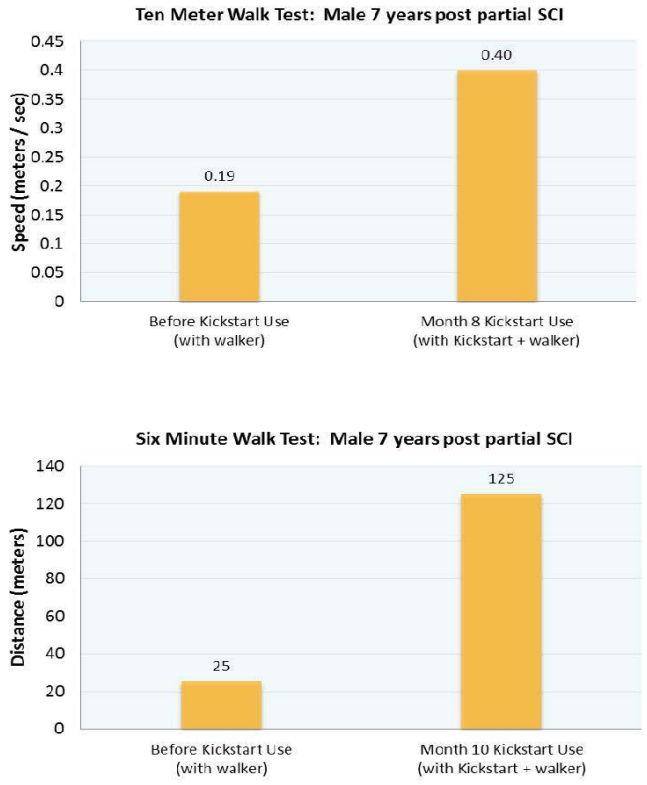

Figure 2: Six minute walk and walking speed data for Case 1 (incomplete Spinal Cord Injury) using Kickstart with a walker.

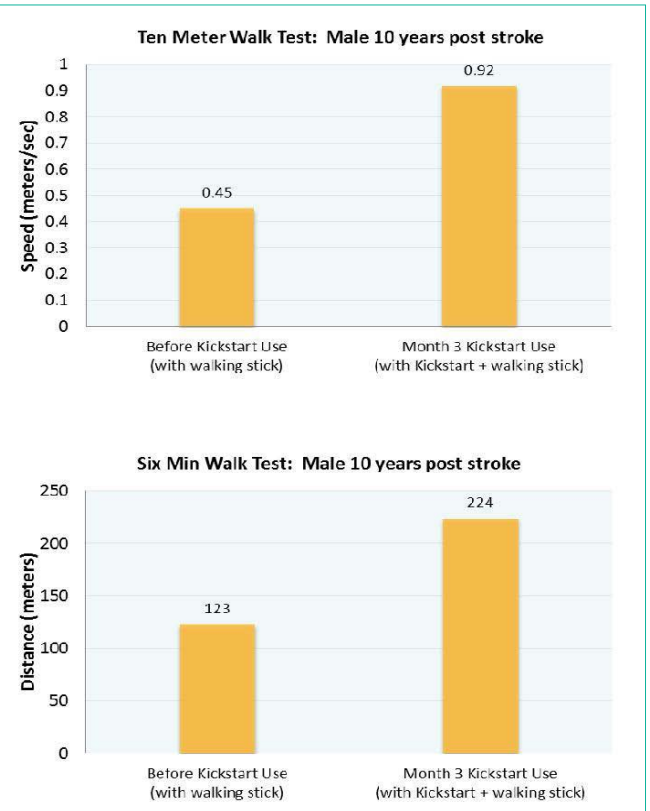

Figure 3: Walking speed and six minute walk data for Case 2 (stroke) using Kickstart and a walking stick.

plantar flexors, and ankle dorsiflexors. Sensation was poor. On the left the subject could feel the sensation of being touched but could not discriminate sharp, dull, or location. He was also unable to discriminate the position of the left hip, knee, or ankle. His sensation was fair on the right for light touch, sharp, dull, and position of the hip, knee, and ankle. Prior to working with Kickstart, his therapy was focused on body-weight supported treadmill training with a GlideTrack™ once a week and aquatic therapy 4 days a week at another rehabilitation site. He used Kickstart in a bilateral configuration for supervised over ground walking once a week for eight months. The Six Minute Walk Test (the distance walked in six minutes) and the Ten Meter Walk Test (time it takes to cover ten meters) were recorded as a measure of endurance and walking speed, respectively. Data collected include the use of Kickstart with a walker.

Case 1 outcomes

With Kickstart, the subject was able to make substantial gains in both walking speed and endurance (Figure 2). Despite a short setback from a revision surgery to replace the stabilization hardware in his spine, his walking speed improved at its maximum to 0.4 m/s, a substantial increase from the 0.2 m/s he was able to achieve without the device and above the threshold considered for limited community ambulation [15,16]. Endurance improved even more dramatically, with six minute walk distances improving from 25 meters to 125 meters, a five-fold increase. During some therapy sessions, the subjects were able walk outside for 30-45 minutes and cover the distance of 500 m. He also perceived an improvement in proprioception in terms of awareness of his knee position in space. Lastly, his right leg function improved enough to permit unilateral use of Kickstart on the left side only.

Case 2: Cerebrovascular Accident

Participant 2 was a male who had a cerebrovascular accident 11 years prior to the study. He lived independently at home, walked independently with a cane and a carbon-fiber ankle foot orthosis on the right and drove his car using the left leg. He could not stair climb reciprocally. This participant presented with right hemiparesis of the arm and leg and expressive aphasia. In the lower right limb, he had 2-/5 strength in his hip flexors, ankle dorsiflexors, and ankle plantar flexors with 3-/5 strength at the knee. He walked with a stiff knee gait and external rotation of the hip which limited his walking speed and efficiency. At home he walked without a cane, but in the community he used a cane. His past activities in physical therapy included strength training, gait training with the Tibion™ bionic leg, and weekly walking on an air-distributed a weighting treadmill system (AlterG™). With a unilateral Kickstart, he performed a series of supervised functional exercises which included squats, knee raises, walking over obstacles, and stair ascents and descents (2x/month for 2 months). He used Kickstart daily for walking at home and in the community. Similar to Case 1, Ten Meter Walk and Six Minute Walk data were recorded. Data presented are with Kickstart and a walking stick.

Case 2 outcomes

Case 2 also demonstrated significant improvements in all metrics (Figure 3). His walking speed improved from 0.5 m/s to 0.92 m/s, fast

enough to be classified as an independent community ambulatory [16]. His endurance also improved dramatically (123 m to 224 m for 6 min walk). A qualitative viewing of his gait showed reduced external rotation and improvement in knee flexion with Kickstart rather than his prior stiff-legged gait. Additionally, the subject also perceived improved awareness of the limb in space and was able to walk reciprocally up and down the stairs in his home with Kickstart. Also by self-report, 12 months after beginning Kickstart use the subject reported he was able to maintain the gains made with Kickstart while walking with only an AFO and a walking stick.

Case 3: Cerebrovascular Accident

Participant 3 was a woman who had a cerebrovascular accident 20 years prior to the study. She lived independently at home, walked independently with a cane for short distances and utilized a Segway for long distance mobility. She could not climb stairs reciprocally. This participant presented with left hemiparesis of the arm and leg. In the lower left limb she had 3/5 strength in her hip flexors, knee extensors, and knee flexors and 2/5 strength in the ankle dorsiflexors. She walked with circumduction at the hip which limited her walking speed and efficiency. Her past activities in physical therapy included strength training and gait training with the Tibion™ bionic leg. She used a unilateral Kickstart daily at home and in the community but did not attend physical therapy. Similar to Case 1, Ten Meter Walk and Six Minute Walk data were recorded. Data presented are with Kickstart and a cane.

Case 3 outcomes

Case 3 also demonstrated significant improvements in all metrics (Figure 4). Her walking speed improved from 0.42 m/s to 0.94 m/s which is fast enough to be classified as an independent community ambulatory [16], as this speed is fast enough to cross the street before a stop light changes. Her endurance also improved dramatically (120 m to 226 m for six minute walk). Additionally, the participant was able to walk reciprocally up and down the stairs in her home with Kickstart. Similar to Case 2, this participant reported that after 12 months of use she was able to maintain her new levels of activity without use of Kickstart.

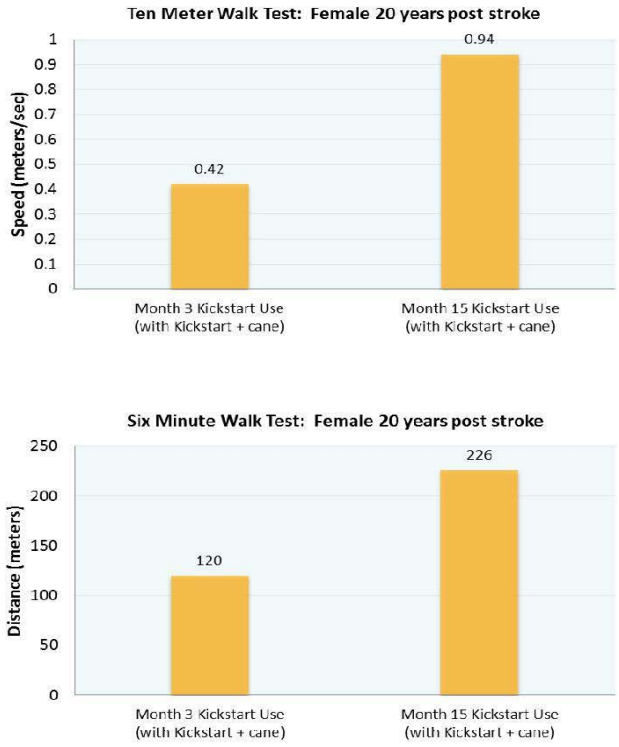

Figure 4: Walking Speed and Six Minute Walk data for Case 3 (stroke). Data is with Kickstart and a walking stick.

Discussion

In this paper we present Kickstart, a practical, affordable alternative to powered exoskeletons to accelerate walking recovery for people with neurological injuries. We also demonstrated its rehabilitative potential with three clinical cases who essentially served as their own controls as a result of plateaued progress in their rehabilitation. In each case, walking speed and endurance improved dramatically to a community level. Studies with larger sample sizes are indicated to explore the efficacy of Kickstart as a neuro-rehabilitation tool as related to the improvement of gait with respect to functional independence. This study is the first evidence presented that Kickstart may play an important role in rehabilitation programs for patients recovering from chronic neurological injuries.

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